Monitoring wooden aircraft structures for compression failure detection

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DGAC study n° 06/084/MQ/FIN "Research into non-destructive compression crack detection methods for wood structures" (February 2008).
Full version available:
http://www.aviation-civile.gouv.fr/html/actu_gd/secu2/securit_rap2.htm

Main objectives: to identify NDT methods for compression failure detection in spars, which are light wooden aircraft structural components

Compression failure

- Structural anomaly that occurs as a fine fracture perpendicular to wood fibres
- Results from significant deformation followed by wood cell compression failure
- Formation accompanied by several transverse fissures in the material

Observation of cracks in wings

Each wing has one (or more) spars attached to the fuselage. For CAP10, the spar consists of two chords in Sitka spruce (*Picea sitchensis*) and two 5 mm thick webs in birch (*Betula pendula*) plywood. Compression failures were located on both the upper and lower wing surfaces, close to the wing/fuselage joint and extending to the landing gear attachments.

Test specimens

- Sitka spruce (*Picea sitchensis*) is the wood species used
- Dimensions: 10 x 60 x 300 mm
- Reference humidity 12% (20°C ± 2°C and 65% ± 5% relative humidity)

Damage tests

Standard axial compression tests to artificially induce a compression failure without destroying the specimens. The failure is produced when the specimen buckles. Tests are stopped by the operator when the typical compression crack wrinkling feature appears.

Selected NDT methods

- Infrared thermography (surface inspection with direct access)
- X-ray analysis (deep inspection without direct access)
- Ultrasound (deep inspection with direct access)
- Acoustic emission (passive detection without direct access – In-service monitoring) Not discussed here

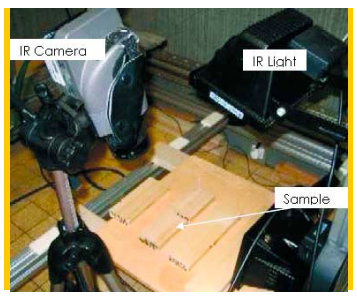
Infrared thermography

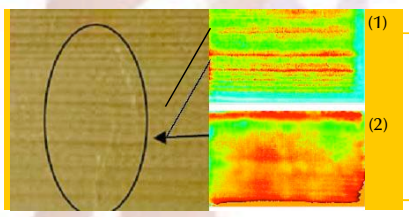
Tests and results by THERMOCONCEPT TREFLE ENSAM, Esplanade des Arts et Métiers, 33 405 Talence cedex, France.

Different techniques and processes were used for defect detection:

- "Front face flash" excitation
- "Front face step" excitation
- Oblique excitation

Tests were also performed after dampening the specimen in the presence of water.





(1) Example of response time image obtained after processing a burst of infrared images

(2) Example of response time image obtained after processing a burst of infrared images and surface moisture penetration in wood

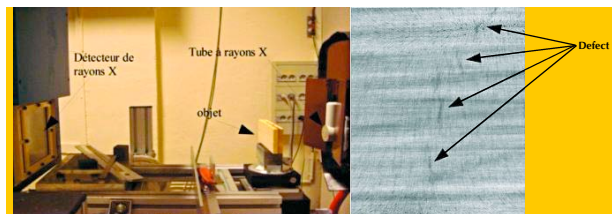
The defect could not be detected, irrespective of the type of excitation or the method used. This type of defect does not seem to bring about a significant modification in the thermo–physical properties of wood for its detection by infrared thermography.

X-rays

Tests and results by the Laboratoire Contrôle Non Destructif par Rayonnements Ionisants (CNDRI) INSA, Lyon, France.

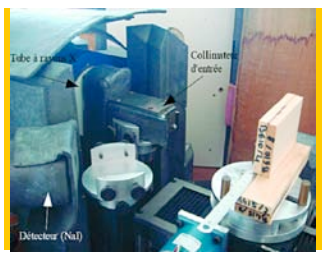
Transmission

Voltage: 35 kV. Intensity: 400 µA. Acquisition time: 1 min
Dark areas highlight compression failures. These dark areas indicate the presence of material that is denser than the surrounding material. This local densification of material at the compression crack location can be explained by buckling followed by very local fibre crushing.



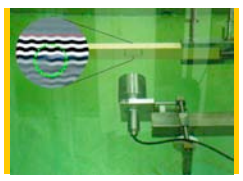
Compton diffusion

Angle θ: 135°. Voltage: 35 kV. Intensity: 400 µA.
Acquisition time: 1 min
Thickness variations do not interfere in the measurement. Access to only one side of the spar, which is more suitable for inspection. But the signal generated by wood is very weak; the sensitivity required to detect a defect has not been achieved.



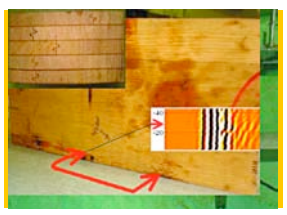
Ultrasound testing with water couplant

Test and results by Laboratoire de Mécanique et d'Acoustique, CNRS, UPR-7051, 13402 Marseille Cedex 20, France



Test on specimens

In B-Scan mapping, anomalies highlight compression cracks (break in the image pattern ≡ acoustic impedance failure).

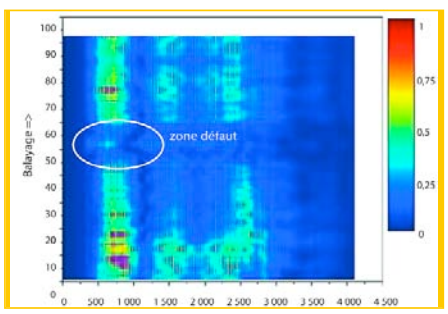


Test on a spar element

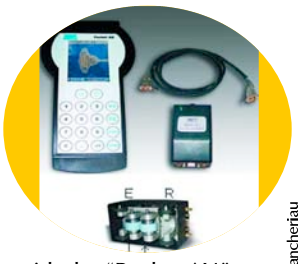
At 1 MHz, in B-Scan imagery (impedance contrast image), underwater type ultrasound detection appears possible.

Ultrasound testing with elastomer couplant

Tests and results by EURO PHYSICAL ACOUSTICS. 94373 Sucy-en-Brie Cedex, France.



B-Scan mapping interpretation is very difficult. Out of 16 tests, 4 detections were possible without any detection on the reference specimen. None of the successful detections were related to small cracks. One large crack was not detected.



Tests with the "Pocket AU" (portable ultrasonic emitter–receiver, 200 kHz and 400 kHz).

CIRAD
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Département des productions fruitières et horticoles

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